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PREVENTION OF 5.56MM ALUMINUM CARTRIDGE CASE BURN-THROUGH

January 1975

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Munitions Development & Engineering Directorate

U.S. ARMY ARMAMENT COMMAND
FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA 19137

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents recent developments in cartridge case coatings designed to prevent the occurrence of burn-through in 5.56mm aluminum cartridge cases. The research work performed determined the effectiveness and general feasibility of five materials: red grip core paste, polyimide varnish (DuPont), The National Aeronautic and Space Administration's (NASA) 45B3 intumescent coating, polysulfide sheeting, and

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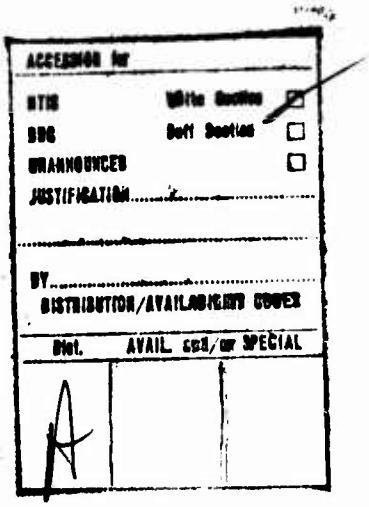
Philadelphia, Pennsylvania 19137. The representatives from Frankford Arsenal were Mr. S. J. Marziano, Technical Supervisor and Ms. Barbara Caldwell, Contracting Officer. The representatives from the Thiokol Chemical Corporation were Dr. Calvin Vriesen, Principal Investigator and Mr. E. C. Ooslerom, Program Manager.

20. ABSTRACT: (Continued)

RTV-734 (Dow Corning) used in combination with other materials. As a result of test firings conducted using the aforementioned materials, two formulations, the NASA intumescenc coating and the polysulfide sheeting, internally applied, emerged as the most successful candidates. In light of the general efficiency demonstrated by these materials, it is concluded that an internally applied case coating material could prove to be most effective in the prevention of burn-through in 5.56mm aluminum cartridge cases.



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INTRODUCTION

A number of interior coatings had been investigated by Frankford Arsenal for efficiency in reducing burn-through erosion. During August 1972, Frankford Arsenal successfully demonstrated the feasibility of aluminum cartridge cases in high performance small caliber ammunition.[1] It had been shown[2] that a gas path through the wall of an aluminum case, through which propellant gas can flow during the internal ballistic cycle, is a precursor to the burn-through phenomenon. Severe erosion of the case occurs during the burn-through and is accompanied by a large flash next to the breech of the test weapon. The effort in this report was conducted by Thiokol Chemical Corporation during 8 August 1972 to 28 February 1973.

Six coatings were investigated for their efficiency in reducing burn-through erosion. Of these, the 45B3 NASA Intumescent Coating, RTV 734 (Dow-Corning), and a core paste, Red Grip, had been shown to be most effective. The reduction of the burn-through phenomenon was considered to be of value since it might give clues to improved coating formulations. Properties of coatings which were considered to be of importance were:

1. Toughness (tear strength)
2. Thermal stability
3. Elastomeric character
4. Insulation capacity

The six lots of cartridges prepared and submitted under this program are listed in the following section with their formulations and results tabulated and discussed in turn.

Prior to this program, the general capability to effectively coat cartridge cases had been demonstrated by submission of a series of samples prepared by the Thiokol Corporation, using NASA's 45B3 formulation. Results are tabulated in the appendix to this report.

EXPERIMENTAL WORK

To simulate case damage that could occur as a result of field use,

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[1]Reed E. Donnard and Thomas J. Hennessy, "Aluminum Cartridge Case Feasibility Study using the M16A1 Rifle with the 5.56mm Ball Ammunition as the Test Vehicle," Frankford Arsenal, Report No. R-2065, November 1972

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[2]W. H. Squire and Reed E. Donnard, "An Analysis of 5.56mm Aluminum Cartridge Case Burn-Through Phenomenon," Frankford Arsenal, No. AD750379, 1972

the outside surface of the cases were grooved longitudinally with a rectangular groove 0.0145 inch wide, 0.007 inch deep, and 0.875 inch long.[3]

Dimensions of case coating thicknesses and groove location were determined at points indicated in Figure 1.

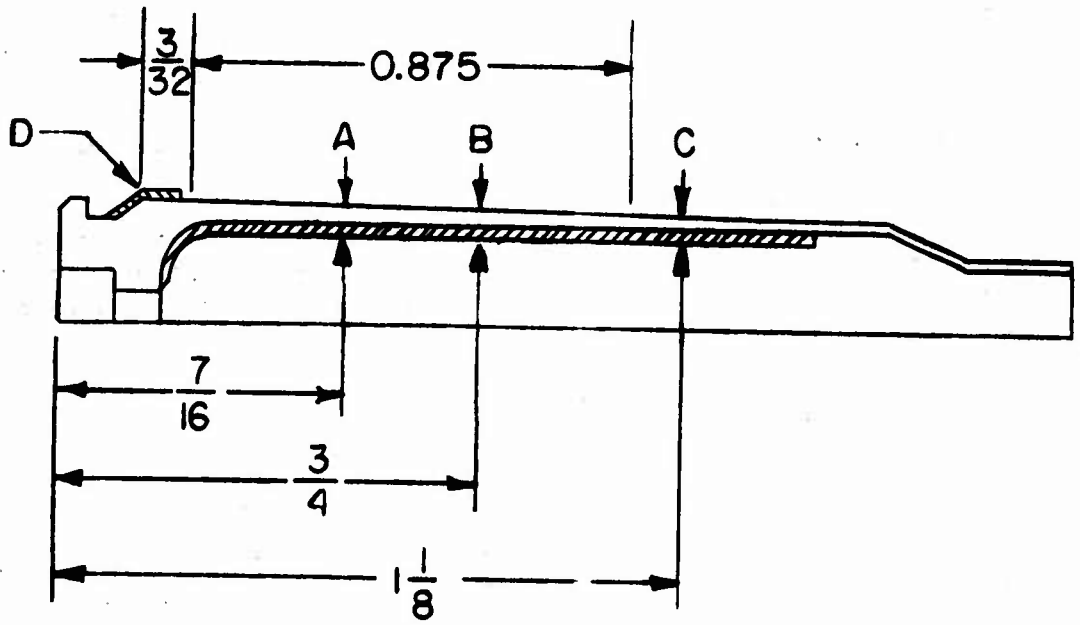


Figure 1. Location Points

[3]Reed E. Donnard and Leonard Skochko, "Induced-Failure Test Procedure For Aluminum Alloy Cartridge Cases," Frankford Arsenal Report No. 6019, June 1971.

LOT 1

Formulation A (Interior)

Component	Parts by Weight (g)
Graphite	39.0
Polysulfide Binder	26.0
Methyl Ethyl Ketone	35.0

This formulation was selected in order to evaluate the effect of graphite with respect to thermal stability and insulation capability. Graphite has been used extensively in rocket motor nozzles. The binder was that used in NASA's 45B3 Intumescent coating:

LP-3 Polysulfide	45.5
EPON 828 Epoxy Resin	45.5
DMP-30 2, 4, 6-Tri(dimethylamino-methyl)phenol	9.0

Methyl ethyl ketone was used to dissolve the components and to facilitate application which was accomplished by a fill and drain procedure. This allows excess material to drain through primer vent hole.

A review of the test data (Table I) and Figure 2 resulted in the following observations:

a. A polysulfide coating cured with an epoxide and applied at a 6-7 grain level in methyl ethyl ketone by a fill and drain procedure is not effective in preventing case burn-through.

b. Failure may have been due to solvent occlusion by the formulation - weights were taken only after cure and not before.

LOT 2

Formulation B (Interior) - Red Grip Filler in RTV 734

The Red Grip Filler was obtained from Red Grip Core Paste (Pennsylvania Foundry, Phila., PA 19124) by washing out the water it contained with acetone and air drying the solids which remained. Methylene chloride was used as a carrier and a fill and drain procedure was utilized to arrive at the desired weight.

TABLE I.
Test Results of Lot 1

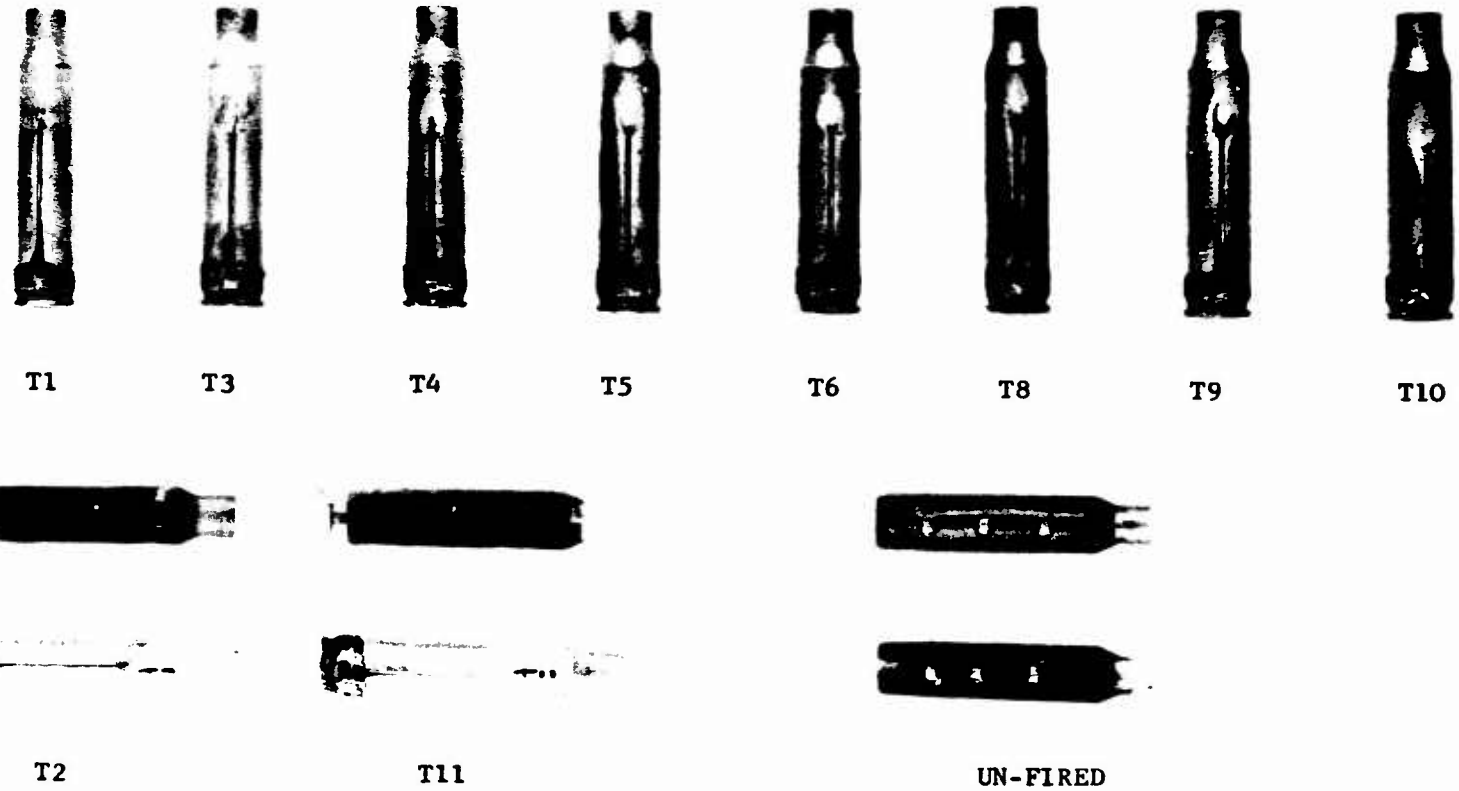
	Component	Parts by Weight (g)
Formulation A:	LP-3	11.87
	ERL-2274	11.87
	DMP-30	2.26
	Graphite (Fisher Tech.)	39.00
	Methyl ethyl ketone	35.00

Application: Applied on interior by fill and drain procedure.
Test Date: 9-6-72
Propellant: WC 846, Lot 46892, M193 bullet, FA41 primer

All weights in grains.

Case No.	Coating Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T1	6.0	0.46	24.0	2560	Medium	M
T2	6.2	0.51	24.0	2750	Medium	M
T3	6.0	0.69	24.0	2931	Large	L
T4	5.9	0.63	24.0	2506	Large	L
T5	6.2	0.84	24.0	2529	Large	L
T6	5.8	0.63	24.0	2973	Large	L
T7	6.2	Sectioned average dimensions: A - 0.0208", B - 0.0162", C - 0.0126"				
T8	7.1	0.57	24.0	2527	Large	L
T9	6.8	0.58	24.0	2972	Large	L
T10	6.8	0.85	24.0	2972	Large	L
T11	6.8	0.92	24.0	2354	Large	L

L = large body, rim, and extractor groove erosion
M = moderate body and rim erosion



LOT #1

TEST DATE: 9-6-72

Figure 2. Formulation A: Polysulfide Graphite

This formulation was examined because it had been shown that both individual components were effective. Tabular data (Table II) and Figure 3 indicate too great a variation in results. This was very likely due to the fact that it was not possible to apply a uniform coating from a suspension.

LOT 3

Formulation C (Exterior) - One coat of Dow-Corning 1200 Primer - Four coats of RTV 734 (10 percent in methylene chloride)

Previous tests at Frankford Arsenal had shown that exterior coatings such as tapes and interior coatings such as RTV 734 were effective in eliminating case burn-through.[4] The cases in this lot were primed with Dow-Corning Primer 1200. This was followed by four coats of RTV 734 at a 10 percent level in methylene chloride. These applications resulted in a tight fit in the chamber of the test weapon. The application on the exterior of the cases was not effective as indicated by tabular data (Table III) and Figure 4. An examination of fired cases containing an interior coating RTV 734 indicated that the material was forced into and partially out of the test groove and apparently was sufficiently tough to prevent the escape of gases. This property apparently is not effective when RTV 734 is placed on the outside of the case.

LOT 4

Formulation D (Exterior) - Six applications of DuPont RK-692

DuPont's "Pyre-M.L." varnish, RK-692, was selected because of its excellent thermal stability. Its expected life at 150°C is over 1000 hours (DuPont Product Bulletin). It is an aromatic polyimide dissolved in xylene and N-methyl pyrrolidinone at a 15 percent level. The solvents must be removed at lower temperatures (100-150°C) before the

[4]Leonard Skochko, Marvin Fosenbaum and Reed E. Donnard, "Aluminum Cartridge Case Concepts Task - Work Summary," Frankford Arsenal Report No. R-3001, March 1974, No. AD9207126

TABLE II.
Test Results of Lot 2

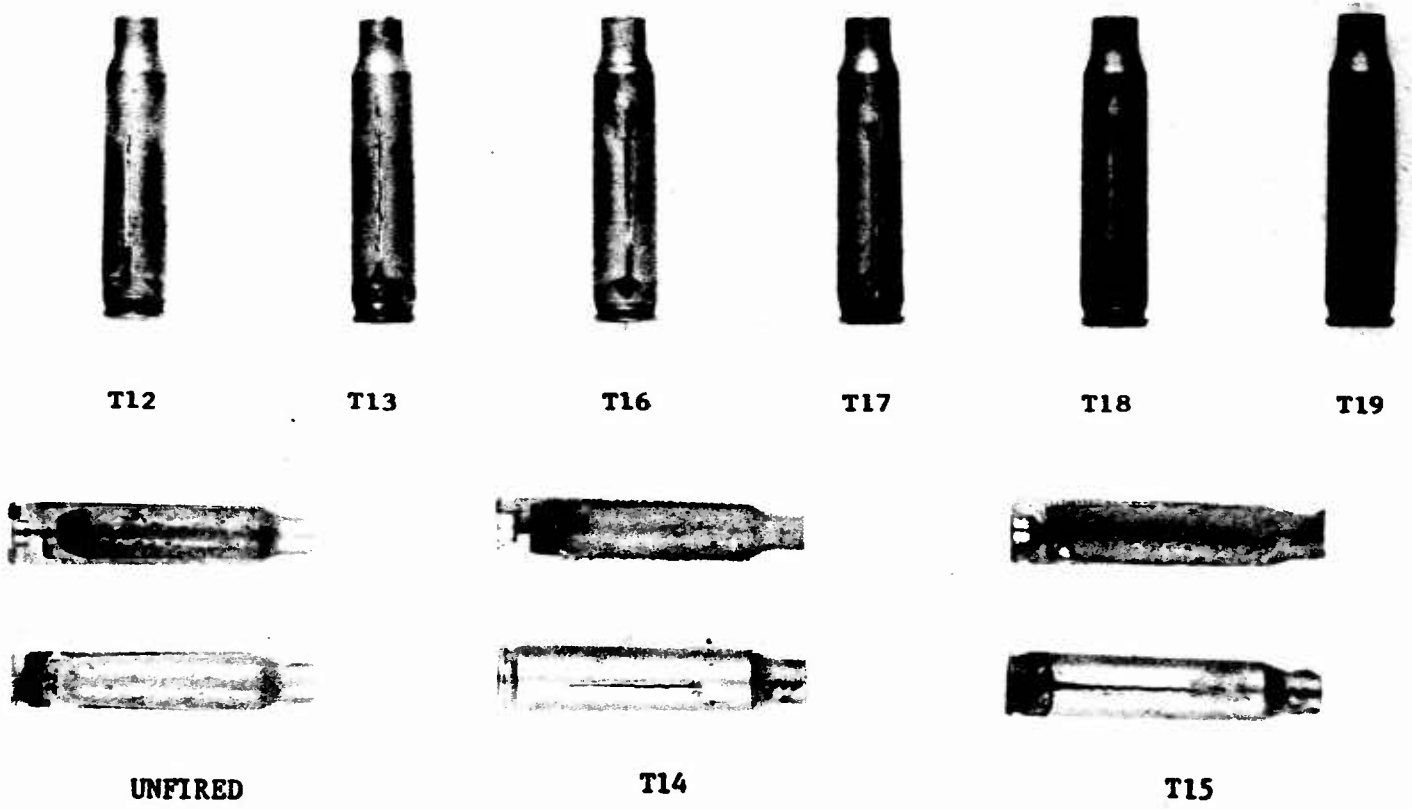
	Component	Parts by Weight (g)
Formulation B:	RTV 734	80
	Red grip filler	20
	Methylene chloride carrier	

Application: Applied on interior by fill and drain procedure.
Test Date: 10-4-72
Propellant: WC 846, Lot 46892, M193 bullet, FA41 primer

All weights in grains.

Case No.	Coating Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T12	7.7	5.83	22.0	2962	-	N
T13	6.2	4.30	23.5	3106	Sparks	S
T14	7.7	3.98	22.0	2942	-	N
T15	5.9	4.75	23.5	3147	Large	L
T16	6.0	4.40	22.0	3105	-	N
T17	6.0	4.60	23.5	3098	-	S
T18	6.2	4.87	23.5	3137	Sparks	S
T19	5.9	4.82	23.5	3206	Sparks	S
T20	5.9	Sectioned sample case				

L = large body, rim, and extractor groove erosion
N = no erosion
S = small body erosion



LOT #2

TEST DATE: 10-4-72

Figure 3. Formulation B: RTV-734 Red Grip Filler

TABLE III.
Test Results of Lot 3

Formulation C: One exterior coat Dow-Corning 1200 Primer, then four exterior coats RTV 734 (10 percent in methylene chloride) each cured one hour with atmospheric moisture.

Test Date: 11-2-72
Propellant: WC 846, Lot 46892, M193 bullet, FA41 primer

All weights in grains.

Case No.	Coating Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T21	0.46	0.94	27.0	3203	Large	L
T22	0.77	0.91	27.0	3226	Large	L
T23	0.62	-				
T24	0.77	-				
T25	0.46	-	Not tested because of results with T21 and T22.			
T26	0.46	-				
T27	0.62	-				
T28	-	Sample case				

L = large body, rim and extractor groove erosion.

T21 T22 T23 (UN-FIRED)

LOT #3

TEST DATE: 11-2-72

Figure 4. Formulation C: Exterior RTV-734

temperature is elevated to accomplish the actual cure. Six applications were necessary to provide a tight fit in the chamber of a test gun, the greatest amount appearing to adhere during the first data of the test firings (Table IV) and the photographs (Figure 5) indicates that good results were obtained.

LOT 5

Formulation E (Exterior) - Two applications of RK-692

Only two coats of RK-692 were applied to the cartridges of this lot, and a tight fit occurred in the chamber of the test piece. The diameter of the cartridges may have been slightly greater than those used in Lot 4. The primer vents in this case were filled with clay and this was covered in turn with RTV 734 to prevent the RK-692 from entering them.

Test results indicated by Table V and photographs (Figure 6) showed that results were completely unsatisfactory. An apparent conclusion is that a tight fit was not obtained in the test weapon. It was the tight fit which constrained the rounds of Lot 4 during firing and prevented rupture. It must be concluded that external coating is not feasible for field use because wear of the chamber could result in a poor fit of the cartridges.

The precautions taken with the primer vent holes were not adequate to exclude traces of the coating, again causing loose primers.

LOT 6

Formulation F (Interior)

Component	Parts by weight (g)
LP-32	77.3
C5500 paste	13.6
Thermax	9.1

Lot 1 polysulfide coatings had been cured with an epoxide in the presence of an amine catalyst. The 38 mil gumstock prepared for this

TABLE IV.
Test Results of Lot 4

Formulation D: Six exterior coats of DuPont RK-692, each one hour at 220° F, then one hour at 280° F, followed by one-half hour at 400° F.

Application: Dip and drain procedure
Test Date: 11-2-72
Propellant: WC 846, Lot 46892, M193 bullet, FA41 primer

All weights in grains.

Case No.	Coating Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T29[1]	0.93	0.05	27.0	3249	Medium	N
T30[2]	1.08	0.05	27.0	3258	Medium	N
T31[3]	0.77	0.01	27.0	3296	None	N
T32	0.77		Damaged in loading.			
T33[2]	0.93	0.94	27.0	3250	Medium	S
T34[4]	1.08	0.49	27.0	3263	Medium	S
T35[1]	0.93	0.36	27.0	3293	Small	L
T36	0.93	0.3791	Sample case			

[1]Loose primer, enlarged primer pocket
[2]Blown primer, enlarged primer pocket
[3]Blown primer, enlarged primer pocket, 1/2 scratch fracture
[4]Blown primer

L = large body, rim, and extractor groove erosion
N = no erosion
S = small body erosion

T29 T30 T31 T33 T34 T35

T36

UN-FIRED

LOT #4

TEST DATE: 11-2-71

Figure 5. Formulation D: Exterior RK-692
(Six applications)

TABLE V.
Test Results of Lot 5

Formulation E: Two coats RK-692 (each 15 minutes at 280-300° F, then final bake 30 minutes at 390-394° F)

Application: Fill and drain procedure
Test Date: 12-14-72
Propellant: WC 846, Lot 46892, M193 bullet, FA41 primer

All weights in grains.

Case No.	Coating Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T37	0.46		Not fired			
T38	0.62	1.52	27.0	3123	Large Loose primer	L
T39	0.46	1.17	27.0	3143	Large Loose primer	L
T40	0.46	-	Not fired because of results with T38 and T39			
T41	0.77	-				
T42	0.77	-				
T43	0.77	0.90	27.0	3158	Large Blown primer	L

L = large body, rim, and extractor groove erosion

T38 T39 T43 T37 (UN-FIRED)

LOT #5

TEST DATE: 12-14-72

Figure 6. Formulation E: Exterior RK-692
(Two applications)

lot was cured with C5500 paste which is composed of lead peroxide with an inhibitor. The use of undiluted lead peroxide results in a very rapid cure.

Rectangles of the gumstock 9/16 inch wide and of a length equal to the circumference of the case were inserted into the cases and positioned with forceps. No adhesive was applied. The positioning was not complete as was evidenced by X-rays taken at Frankford Arsenal (Figure 7). Test results (Table VI) and photographs indicated that this technique was very effective when the inserts were positioned correctly. The insert in Case T43 was in the best position, those in Cases 45 and 46, while not positioned well, did adequately cover the interior under the test groove. Observation of the fired rounds showed that the polysulfide was forced out into the test groove as was RTV 734.

The test results indicate that this polysulfide formulation is effective in preventing erosive burn-through at the level tested (6 grains). An advantage of this formulation is its cost (0.96/lb) as compared to RTV ($4.50/lb).

Results obtained with Lot 6 as compared to those obtained with Lot 1 may have been due to:

a. The type of cure used with the polysulfide

b. The solvent application used with Formulation A

LOT 7

Formulation G (Interior)

The polysulfide formulation in Cases 50-53 was the same as used in Cases 43-49 but was not filled with Thermax filler. The formulation was weighed into the cases and they were spun at such a speed as to properly position the liner and cured under a heat lamp for 12 hours. The test data (Table VII) and Figure 8 indicate that this procedure was partially effective.

The use of Thermax filler and a mixing head for the polysulfide and curative (to considerably reduce cure time) could provide results similar to those obtained with Formulation F.

TABLE VI.
Test Results of Lot 6

	Component	Parts by Weight (g)
Formulation F:	LP-32	77.3
	C5500 paste	13.6
(Company Proprietary)	Thermax	9.1

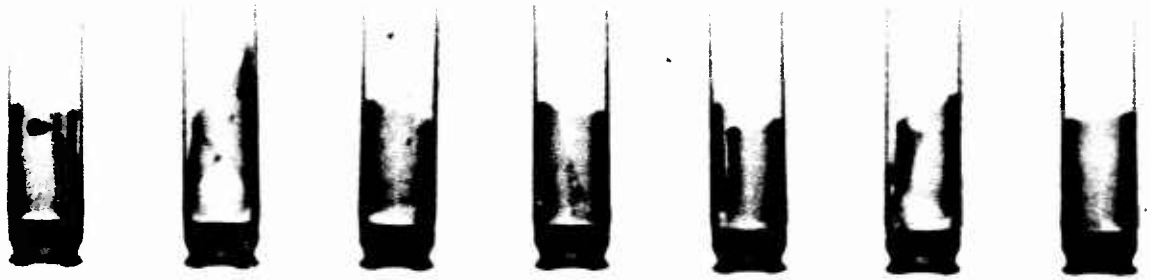
Application: Rectangles 38 mil gumstock, 9/16 inch wide slipped into case, not bonded.
Test Date: 2-15-73
Propellant: Blend 4/1, WC 846/WC 680, M193 bullet, FA41 primer

All weights in grains

Case No.	Liner Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T43	6.1	0.21	23.5	3154	None	N
T44	6.2	0.92	23.5	3053	Large	L
T45	6.1	0.26	23.5	3118	None	N
T46	5.9	0.28	23.5	3156	None	N
T47	5.9	0.34	23.5	3152	Small	S
T48	6.1	0.72	23.5	3156	Small	S
T49	6.1	0.30	23.5	3131	Small	S

L = large body, rim, and extractor groove erosion
N = no erosion
S = small body erosion

POLYSULFIDE - C5500 PASTE - THERMAX



T 49 T 42 T 47 T 46 T 45 T 44 T 43

POLYSULFIDE - C5500 PASTE

T 50 T 52 T 51 T 50

Figure 7. X-Ray Views of Formulations: F - Polysulfide - C5500 Paste - Thermax; G - Polysulfide - C5500 Paste

TABLE VII.
Test Results of Lot 7

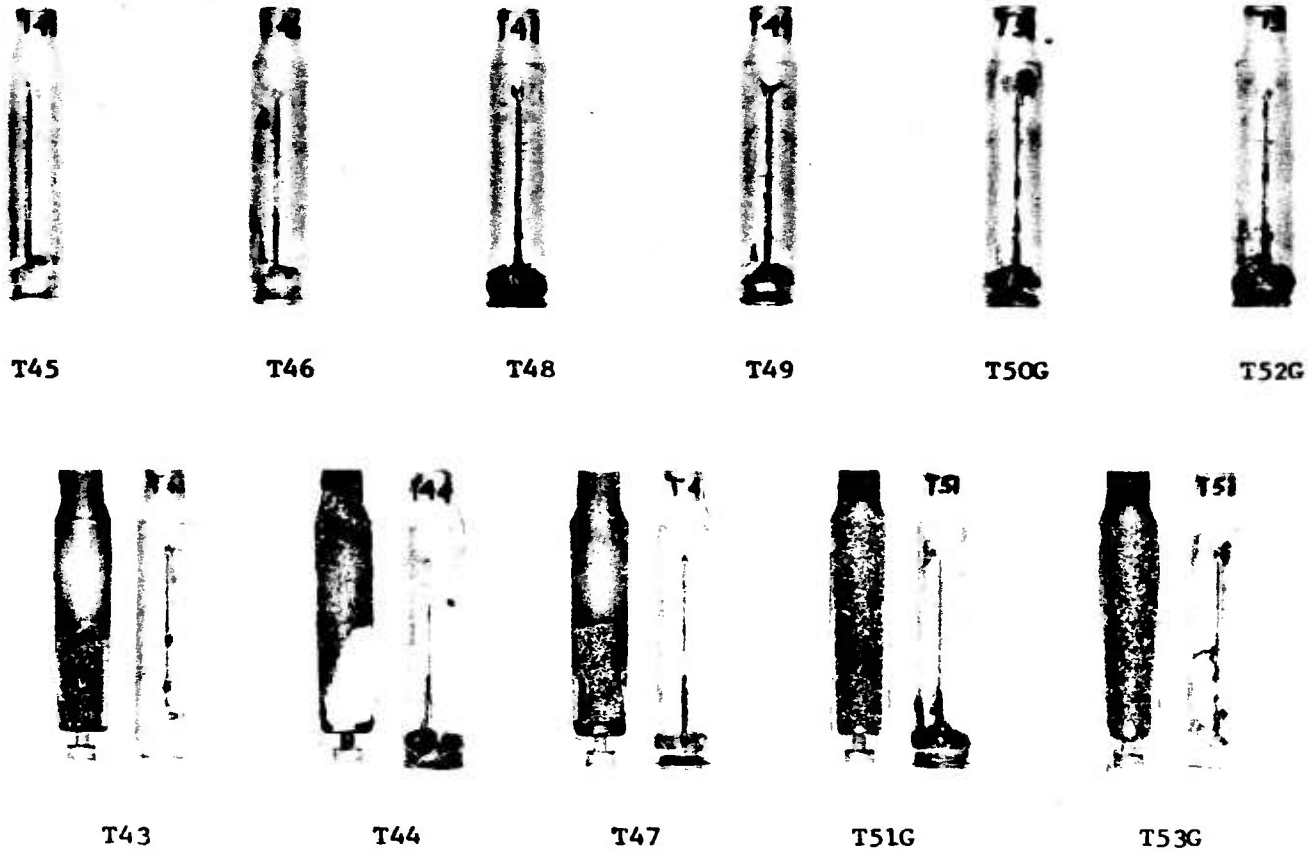
	Component	Parts by Weight (g)
Formulation G:	LP-32	85.0
	C5500 paste	15.0

Application: Weighed in, spun and cured 12 hours with heat lamp.

Case No.	Coating Weight	Dimension A* (in.)	Weight Loss in Firing	Charge Weight	Velocity (fps)	Breech Flash	Erosion
T50	5-6	0.020	0.61	23.5	3219	Small	S
T51	5-6	-	0.83	23.5	3175	Large	M
T52	5-6	-	1.11	23.5	3113	Large	M
T53	5-6	-	0.69	23.5	3205	None	N

M = moderate body and rim erosion
N = no erosion
S = small body erosion

*See Figure 1



Lot #6

TEST DATE: 2-15-73

Figure 8. Formulation F: Polysulfide - C5500 Paste - Thermax
Formulation G: Polysulfide - C5500 Paste

Lot 8

Qualification Effort

The interior of a series of 5.56mm cartridge cases was lined with the NASA 45B3 Intumescent Coating. The composition of the NASA formulation follows:

	Component	Parts by Weight (g)
Part A:	LP-3 Polysulfide	14.1
	Ammonium salt of 4-nitroaniline-2-sulfonic acid	57.0
	Methyl Ethyl Ketone	28.9
Part B:	Shell 828 Epoxide Resin	14.1
	Toluene	4.7
Part C:	Tri (dimethylamino methyl) phenol	2.8
	Toluene	2.8

Results of test firings are shown in Table VIII and in Figures 9 through 13. Eight grains of the coating appear to be necessary to prevent burn-through.

CONCLUSIONS

The most effective coating was a sheet of a proprietary formulation, composed of a polysulfide which was cured with an oxidizing curative, and contained Thermax as a filler. A similar formulation containing no Thermax and cured in the cases while they were rotated was found to be less effective. Little improvement was noted when the polysulfide was cured with an epoxide and applied in a solvent.

A combination of two candidates which had been shown to be effective was examined. These were the filler contained in Red Grip Core Paste and RTV-734. The combination was applied in methylene chloride solvent. Results were not satisfactory.

The silicone RTV-734 was applied externally but found to be ineffective. RK-692 polyimide varnish (DuPont) as an external coating was effective only when a tight fit was obtained in the test weapon. It was concluded that such an external coating is not feasible for field use because wear of the chamber could result in a poor fit for the cartridge.

Results of a qualification effort are included in Table VIII This involved the application of the NASA Intumescent Coating 45B3. It appeared that at least eight grains per cartridge of this coating were necessary to be effective.

The promising results obtained with the polysulfide sheeting indicate that this approach should be explored further. One procedure would be to cure the polysulfide in the form of cylinders which could be inserted into the cartridge cases.

RECOMMENDATIONS

In light of the effectiveness demonstrated by the case coatings tested, it is recommended that:

1. The concept of utilizing interior cartridge case coatings to prevent the occurrance of burn-through be further explored.

2. The Polysulfide Sheeting formulation, the most effective material tested, be further tested and evaluated.

3. The NASA 45B3 Intumescent Coating based on its effectiveness as tested, be also further investigated.

TABLE VIII.
Test Results of Qualification Lot

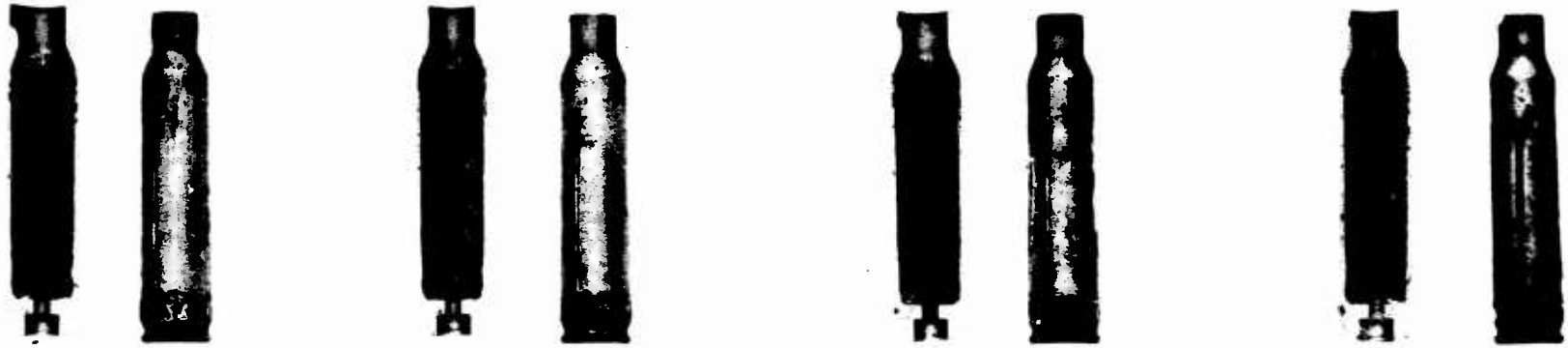
Formulation: NASA 45B3
Application: Fill and drain, interior coating
Test Dates: 3-17-72 and 3-27-72
Propellant: WC 486, Lot 46892, M193 bullet, FA41 primer

All weights in grains.

Case No. (Rd)	Coating Weight	Weight Loss in Firing	Charge Weight	Velocity (fps)	Results	
					Breech Flash	Erosion
13	2.85	1.44	-	3175	Large	L
14	2.82	1.34	-	3159	Large	M
17	3.16	1.33	-	3216	Large	M
21	3.29	1.78	-	3163	Large	M
15	3.81	1.21	-	3137	Medium	M
16	3.82	0.90	-	3260	Small	S
18	3.78	1.56	-	3153	Large	L
19	3.95	1.16	-	3158	Large	M
22	3.70	1.58	-	3158	Large	L
1	4.47	1.19	-	3100	Small	S
9	4.50	1.46	-	3097	Small	M
10	4.73	0.88	-	3111	Large	M
11	5.20	1.17	-	3101	Small	S
23	5.19	1.31	-	3127	Large	L
29	6.66	1.09	24.0	3145	None	M
30	7.53	1.17	23.0	3040	None	N
31	7.25	1.15	24.0	3148	None	S
34	7.67	1.24	23.4	3068	Large	M
37	7.47	1.17	23.3	3124	Large	M
39	6.50	1.29	24.2	-	Large	L
50	6.79	0.96	24.0	3120	Large	L
51	6.13	0.95	24.4	3205	None	N
25	8.11	1.10	23.1	3039	None	N
26	8.35	1.04	23.0	3047	None	N
27	8.11	1.05	23.1	3029	None	N
28	8.46	1.11	23.0	3031	None	N
33	8.57	1.13	22.8	3034	None	S
36	8.60	1.38	22.8	3031	None	S
38	8.31	1.18	23.0	3009	Medium	S

N = no erosion
L = large body, rim and extractor groove erosion
M = moderate body and rim erosion
S = small body erosion

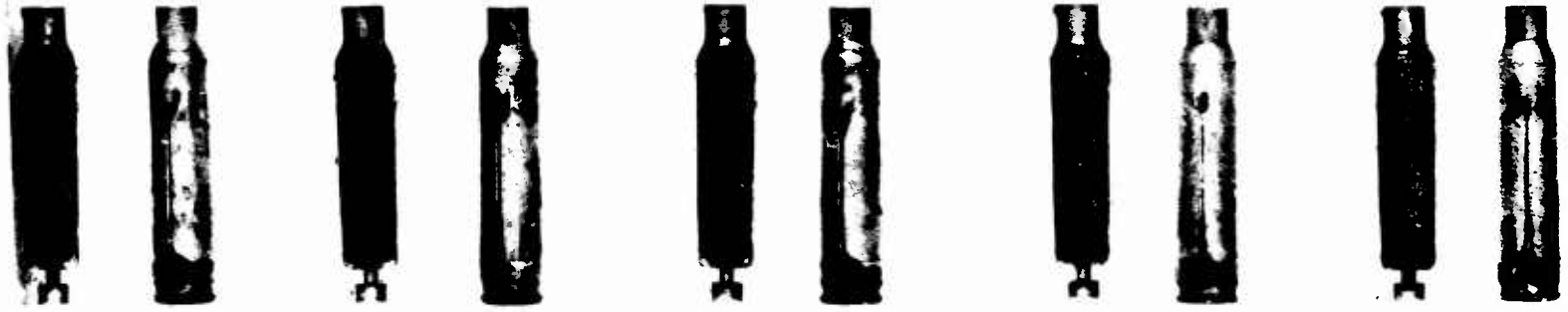
5.56mm Case
WC-846 AL-46892 (26.5 grs)
Intumescent Coating - 45B3
Groove - 0.0145"W x 0.007"D x 0.875"L



RD-13 RD-14 RD-17 RD-21

Figure 9. Intumescent Coating 45B3 (3 grains)

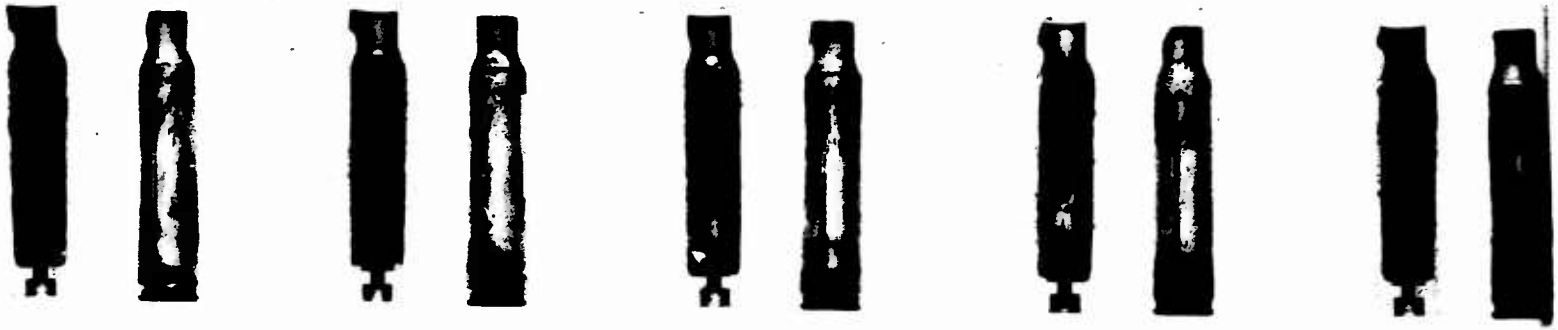
5.56mm Case
WC-846 AL-46892 (25.75 grs)
Intumescent Coating - 45B3
Groove - 0.0145"W x 0.007"D x 0.875" L



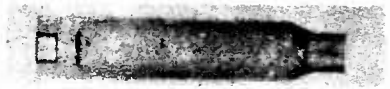
RD-15 RD-16 RD-18 RD-19 RD-22

Figure 10. Intumescent Coating 45B3 (4 grains)

5.56mm Case
WC-846 AL-46892 (25.0 grs)
Intumescent Coating - 45B3
Groove - 0.0145"W x 0.007"D x 0.875" L



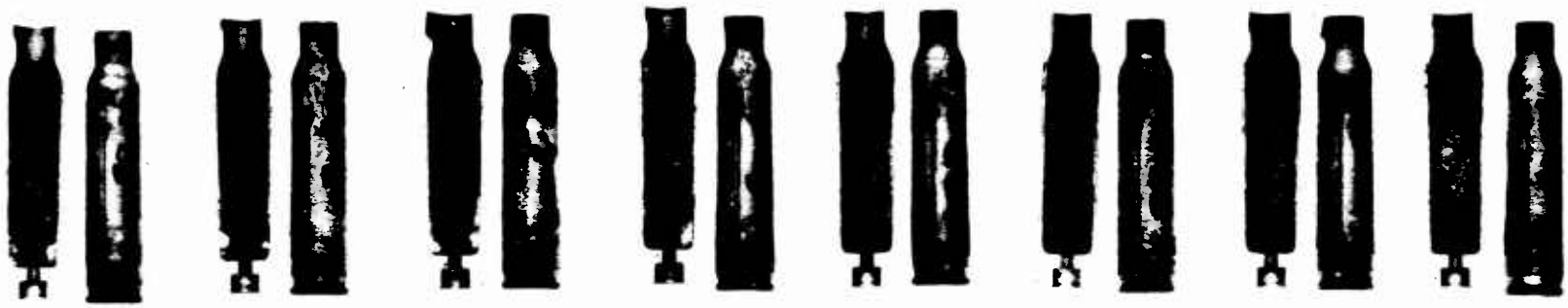
RD-1 RD-9 RD-10 RD-11 RD-23



Un-fired

Figure 11. Intumescent Coating 45B3 (5 grains)

5.56mm Case
WC-846 AL-46892
Intumescent Coating - 45B3
Groove - 0.0145"W x 0.007"D x 0.875" L



RD-29 RD-30 RD-31 RD-34 RD-37 RD-39 RD-50 RD-51

Un-fired

Figure 12. Intumescent Coating 45B3 (6.7 grains)

5.56mm Case
WC-846 AL-46892
Intumescent Coating - 45B3
Groove - 0.0145"W x 0.007"D x 0.875" L

RD-25 RD-26 RD-27 RD-28 RD-33 RD-36 RD-38

Un-fired

Figure 13. Intumescent Coating 45B3 (8.9 grains)

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